Three-Dimensional Computational Modeling of a Barricaded Munitions Stack Within a Temporary Munitions Storage Area

Richard E. Lottero

Explosives Technology Branch

US Army Research Laboratory

19 June 2001

Support and Resources

- Customer: US Army Defense Ammunition Logistics Activity
  - Supporting analysis to prevent a chain-reaction destruction of a temporary munitions storage area if a munitions stack is initiated
- HPCMP Major Shared Resource Center
  - US Army Research Laboratory
  - Aberdeen Proving Ground, MD
- IBM SP Power3
  - 512 processor configuration
  - Run during pioneer mode
  - 120-processor job
  - Final runs totaled approximately 20,000 cpu-hours

Situation

- Field-Expedient munitions storage area
- Detonation of a donor munitions stack
  - 4,000 kg NEW (nominal) of Composition B
  - 72 pallets of 155-mm M107 rounds
- Water barricade
  - Trapezoidal cross section
  - Constructed like Federal Fabrics-Fibers, Inc., water bag design
- Acceptor munitions stack
- 10-foot (3.05-m) standoff

Objective

- Determine the blast and impact loading on the acceptor stack
  - Model this in a 3-D coordinates spatial system
  - Detonation of the donor stack
  - Dynamic response of the water barricade
  - Blast and impact loading on the acceptor stack
- Compare with previously reported 2-D computational results
- Assess possible implications regarding quantity-distance relief
  - Does the use of such a barricade eliminate some of the known or suspected modes of stack-to-stack propagation?

Donor Munitions Stack
2-D & 3-D Computations

- Munitions
  - 72 pallets, 8 rounds each of M107 155-mm projectiles
    - 3 pallets high, 4 wide, six deep
  - 6.98 kg (15.4 lbm) composition B in each round
  - Total explosive mass 4,024 kg (8,870 lbm)
    - Nominal for computations: 4,000 kg
- Dimensions
  - Height 2.44 m (8.00 ft)
  - Width 2.94 m (9.63 ft)
  - Depth 2.19 m (7.20 ft)
- Total mass (explosives, casings, packaging, etc.)
  - 26,029 kg (57,384 lbm)

Trapezoidal Water Barricade

- Based on Federal Fabrics-Fibers, Inc., water bag design
- Trapezoidal cross-section to mimic a pyramid of long water bags
  - Height 2.44 m (8.00 ft)
  - Sides sloping at a 30-degree angle to the vertical
    - Width at top 1.00 m (3.28 ft)
    - Width at base 3.82 m (12.52 ft)
  - Mass of water/cm of depth is 58.71 kg/cm
    - Solid cross section (no air gaps, no bag material)

Experiment at China Lake
3.05-m (10-ft) Standoff

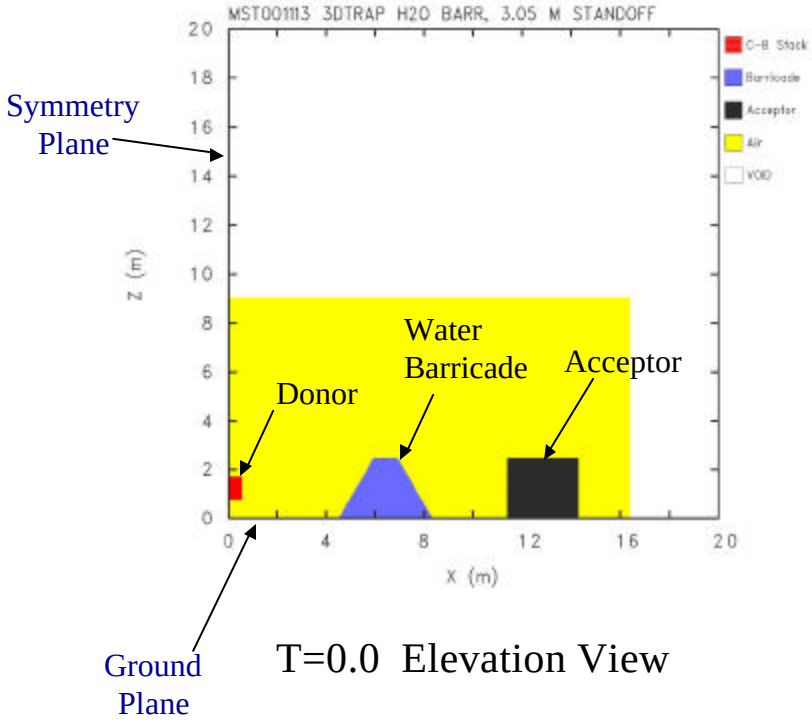
- Donor Stack
  - 576 M107 155-mm projectiles
  - Pallets 6 wide, 6 deep, 2 high
    - Width 2.06 m (6.75 ft)
    - Depth 4.13 m (13.55 ft)
    - Height 1.58 m (5.2 ft)
- Water Barricade
  - 3 bags
    - 1.37 m (54 inch) diameter
    - Pyramid of 3
    - Length 7.01 m (23 ft)
- Acceptor stack
  - Various worst-case munitions

3-D Computational Layout
3.05-m (10-ft) Standoff

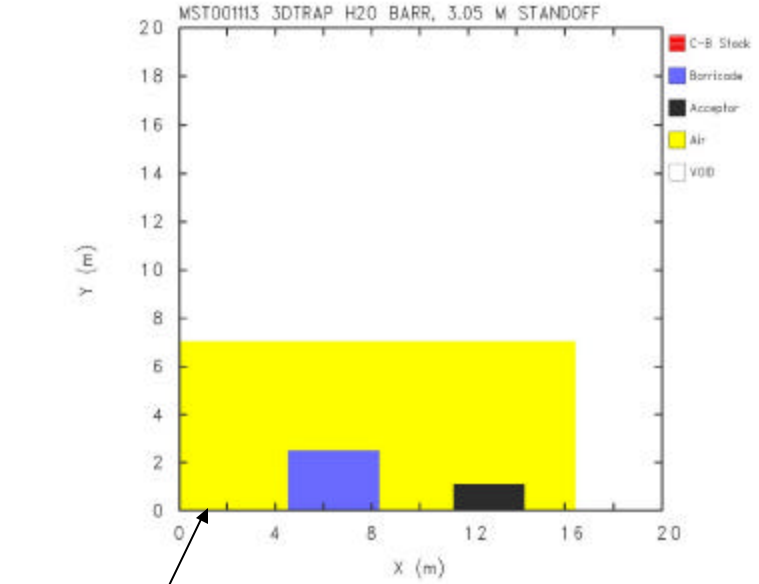
- Donor Stack (used two symmetry planes)
  - "Virtual" full dimensions (used two symmetry planes)
    - Height 2.44 m (8.00 ft)
    - Width 2.94 m (9.63 ft)
    - Depth 2.19 m (7.20 ft)
  - Actual: A condensed rectangular parallelepiped of Composition B suspended with its geometric centerline on the geometric centerline of the "virtual" stack
- Acceptor stack (used one symmetry plane)
  - Actual dimensions equal to the donor stack "virtual" dimensions
  - Solid rectangular parallelepiped of iron
- Water barricade (used one symmetry plane)
  - Reference cross section
  - Full Depth 4.986 m (16.36 ft)

The 3-D Computational Flow Field

All Objects at Rest



T=0.0 Elevation View

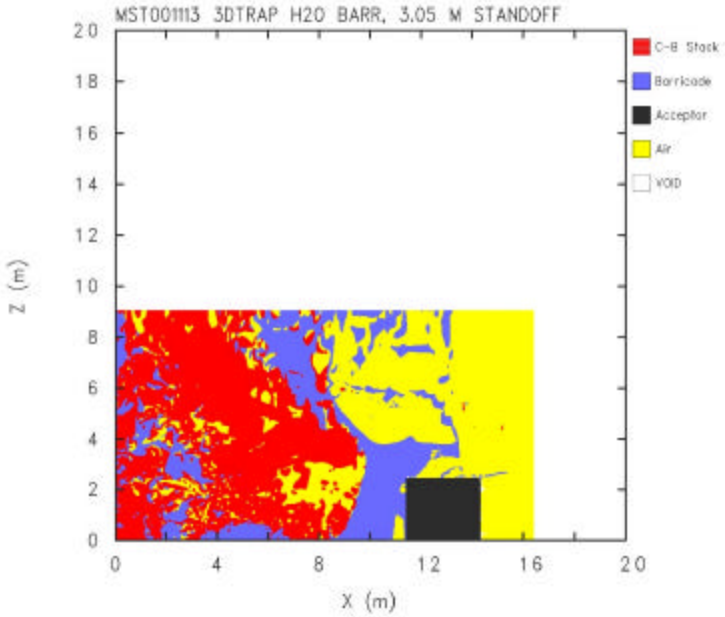


T=0.0 Plan View

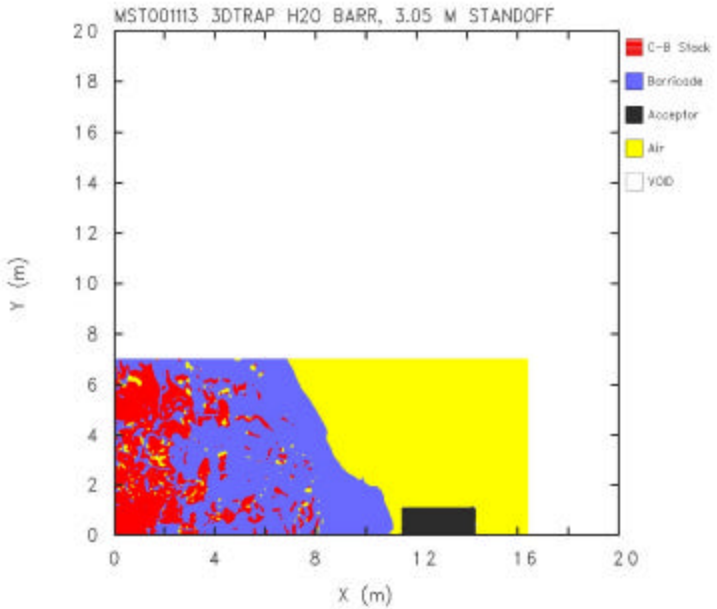
Initial Flow Field Configuration

Fully Coupled Computation 3DC

The 3-D Computational Flow Field



T=47.40 ms Elevation View

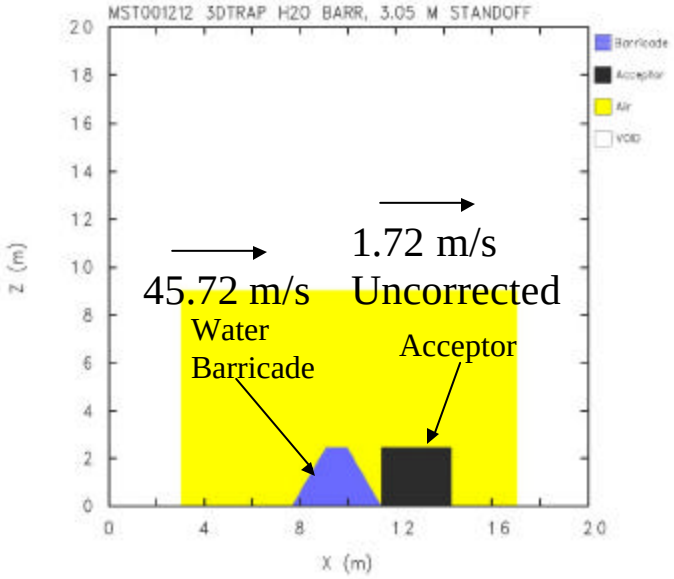


T=47.40 ms Plan View

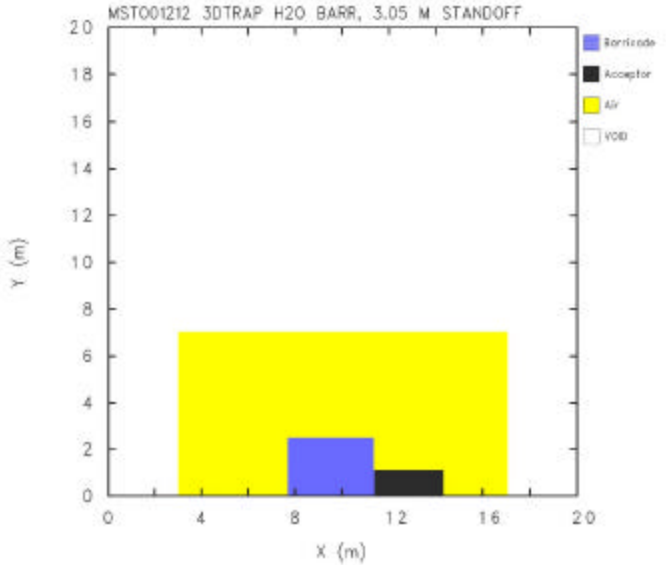
Final Flow Field Configuration

Fully Coupled Computation 3DC

The 3-D Computational Flow Field



T=47.40 ms Elevation View

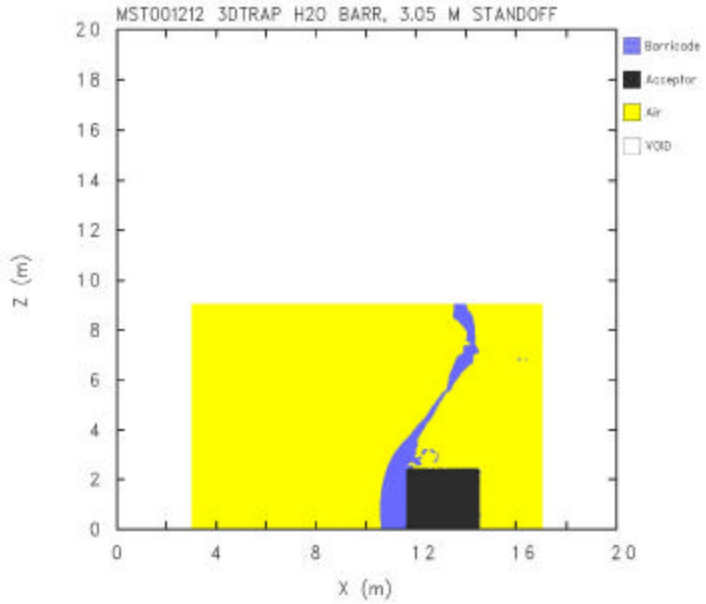


T=47.40 ms Plan View

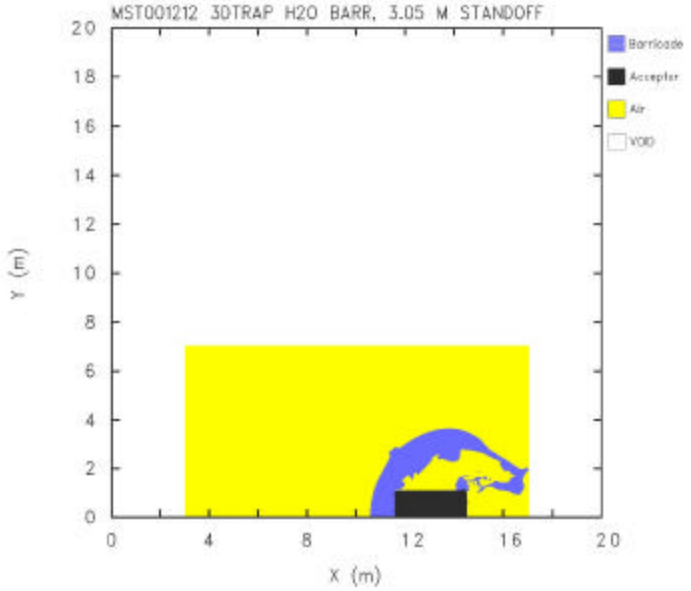
Initial Flow Field Configuration

Uncoupled Computation 3DU

The 3-D Computational Flow Field



T=131.74 ms Elevation View

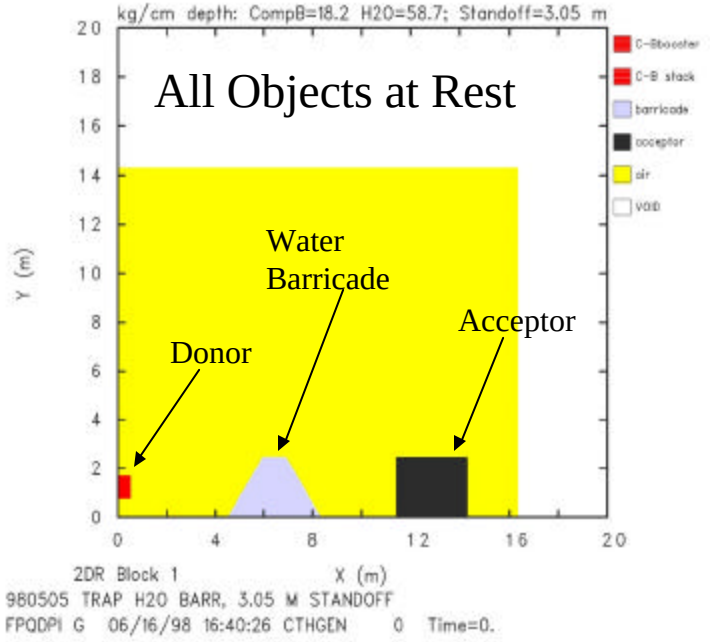


T=131.74 ms Plan View

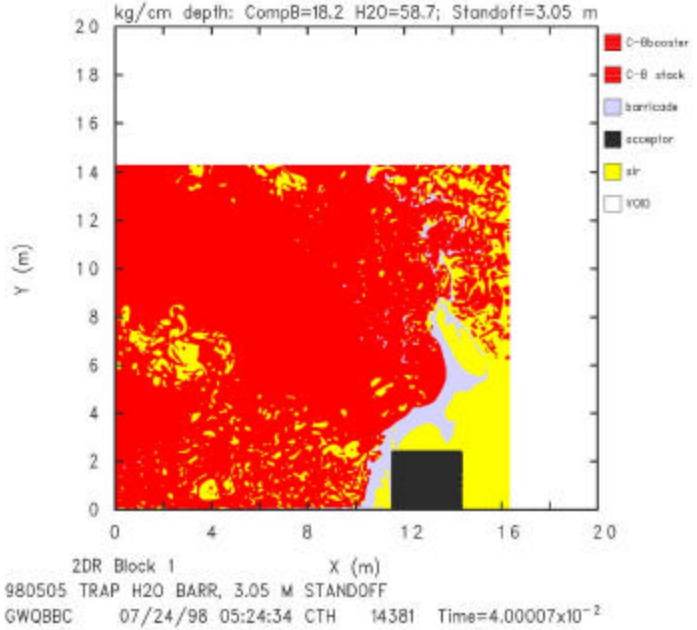
Final Flow Field Configuration

Uncoupled Computation 3DU

The 2-D Computational Flow Field



Initial at T=0.00

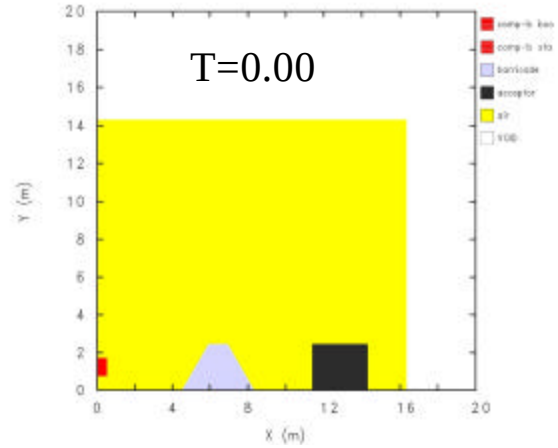


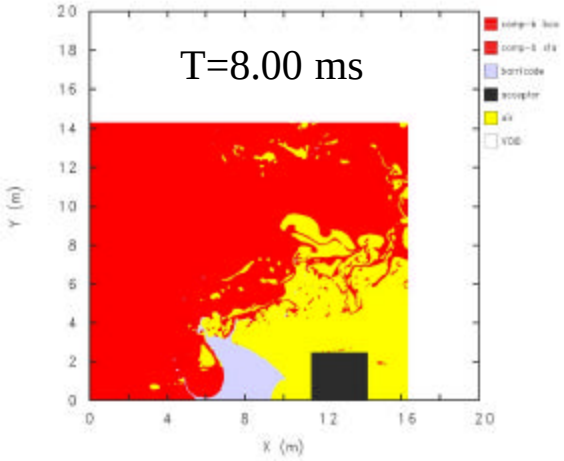
Final at T=40.00 ms

Flow Field Configurations

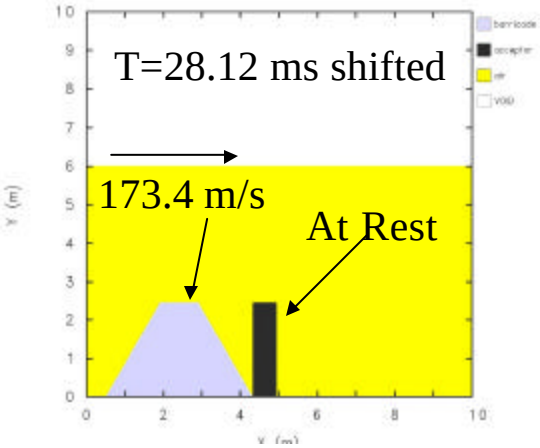
Fully Coupled Computation 2DC

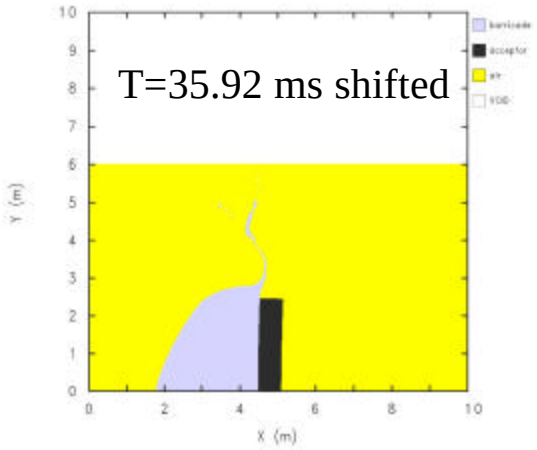
The 2-D Computational Flow Fields, Coupled & Uncoupled





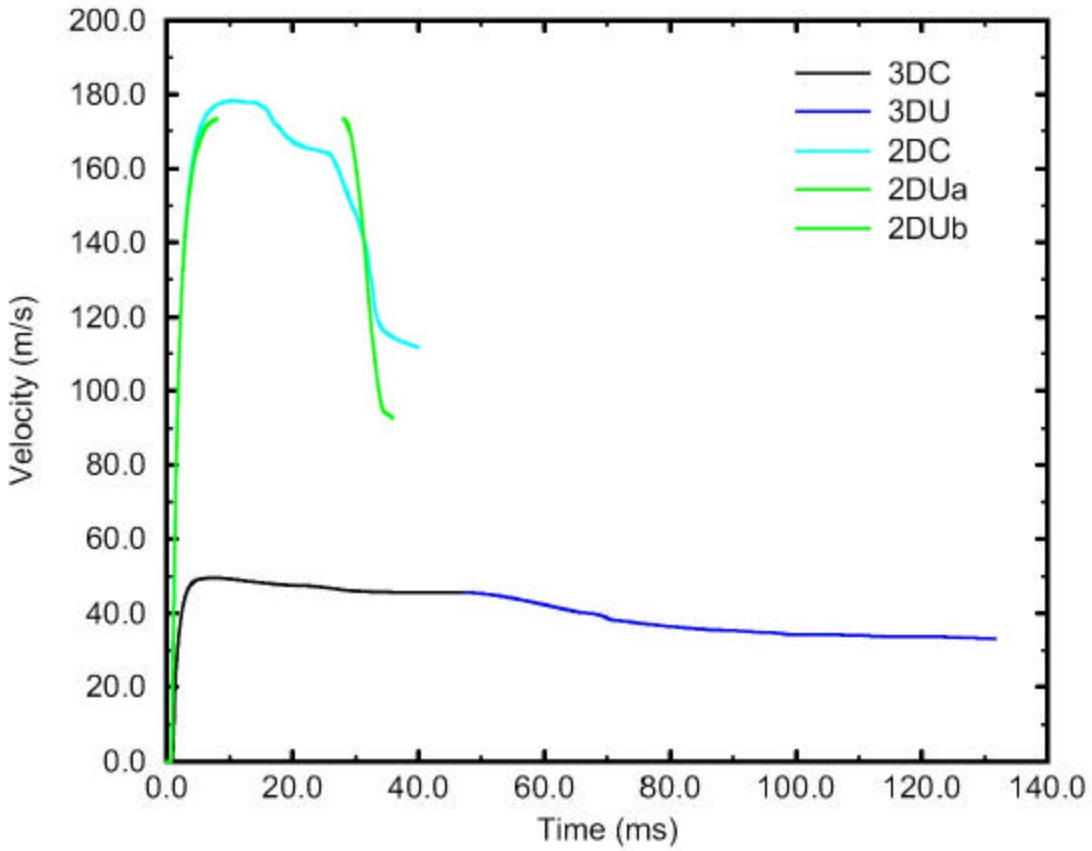
Coupled 2DUa





Uncoupled 2DUb

Barricade X-Direction Velocity: 3-D & 2-D



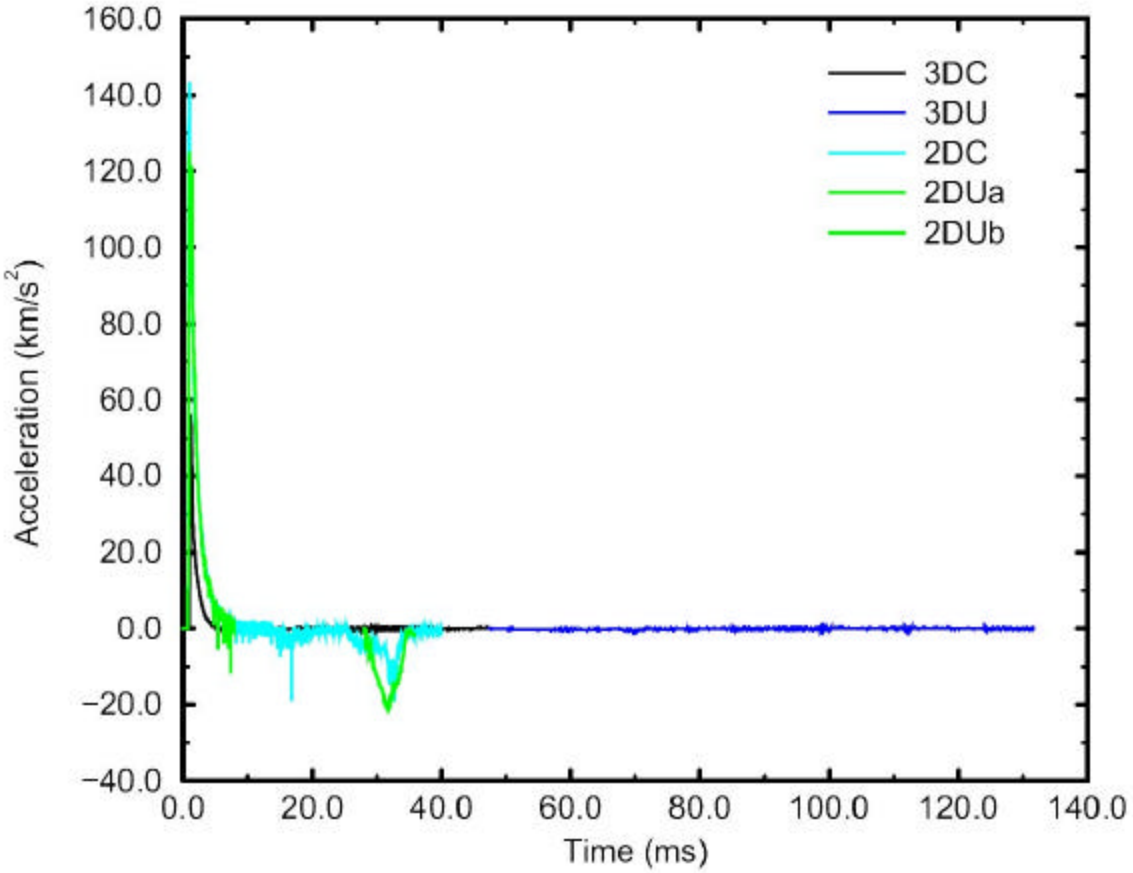
Peak Values

3DC = 49.63 m/s

2DC =178.2 m/s

2DUa = 173.4 m/s

Barricade X-Direction Acceleration: 3-D & 2-D



Peak Values

3DC = +56.28 km/s/s

3DC & 3DU = -0.99 km/s/s

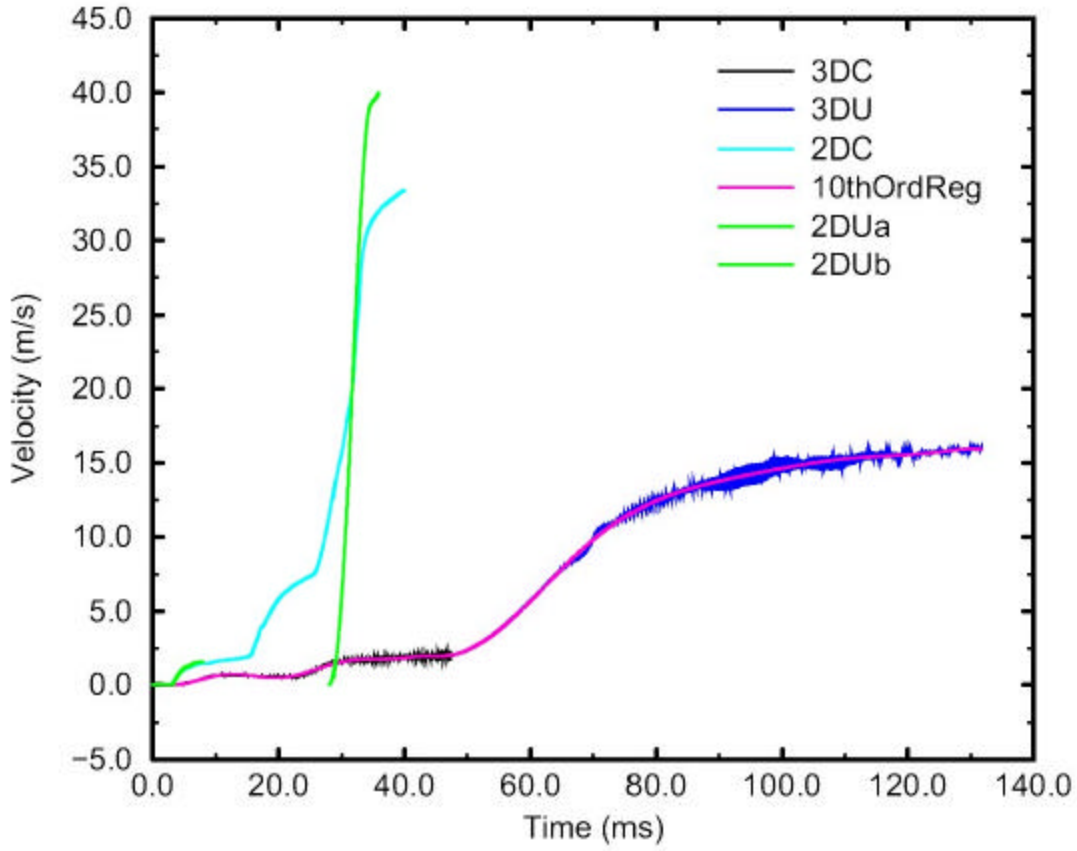
2DC = +143.4 km/s/s

2DC = -19.22 km/s/s

2DUa = +125.2 km/s/s

2DUb = -20.89 km/s/s

Acceptor Stack X-Direction Velocity: 3-D & 2-D



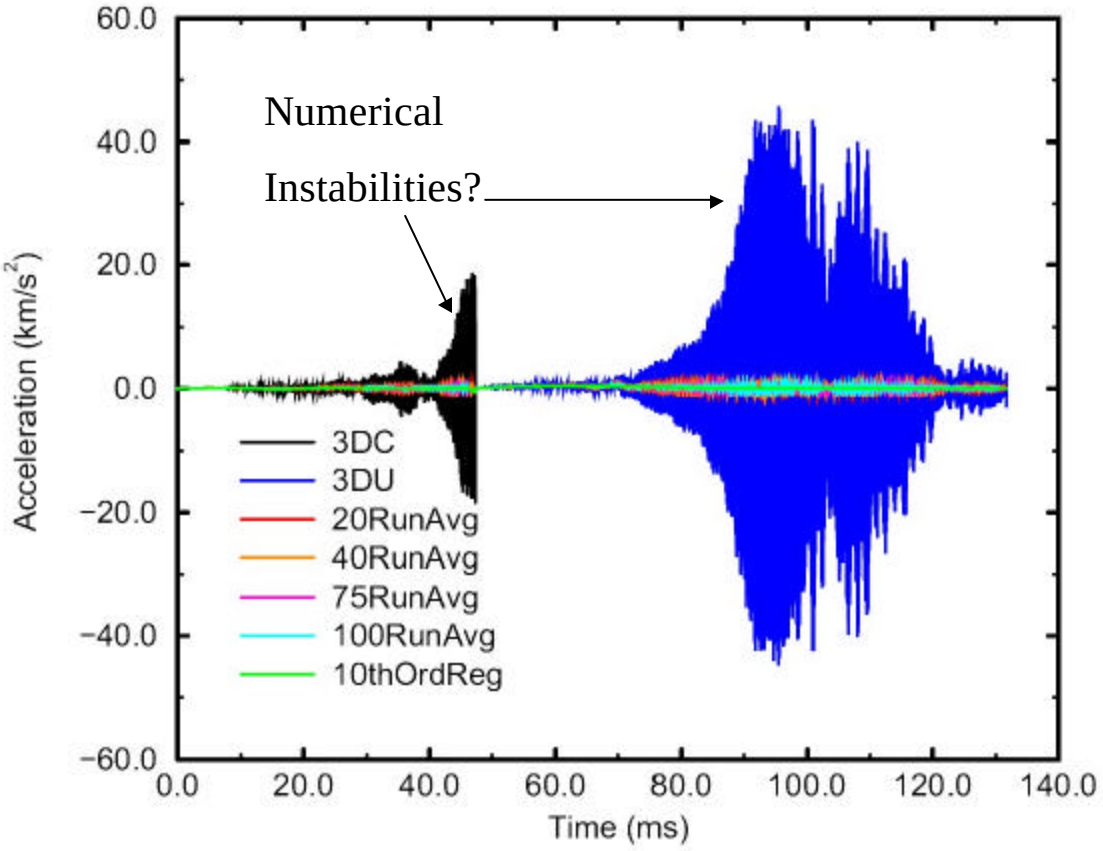
Peak Values

3DC = 16.07 m/s

2DC = 33.40 m/s

2DUb = 39.95 m/s

Acceptor Stack X-Direction Acceleration: 3-D



Peak Values

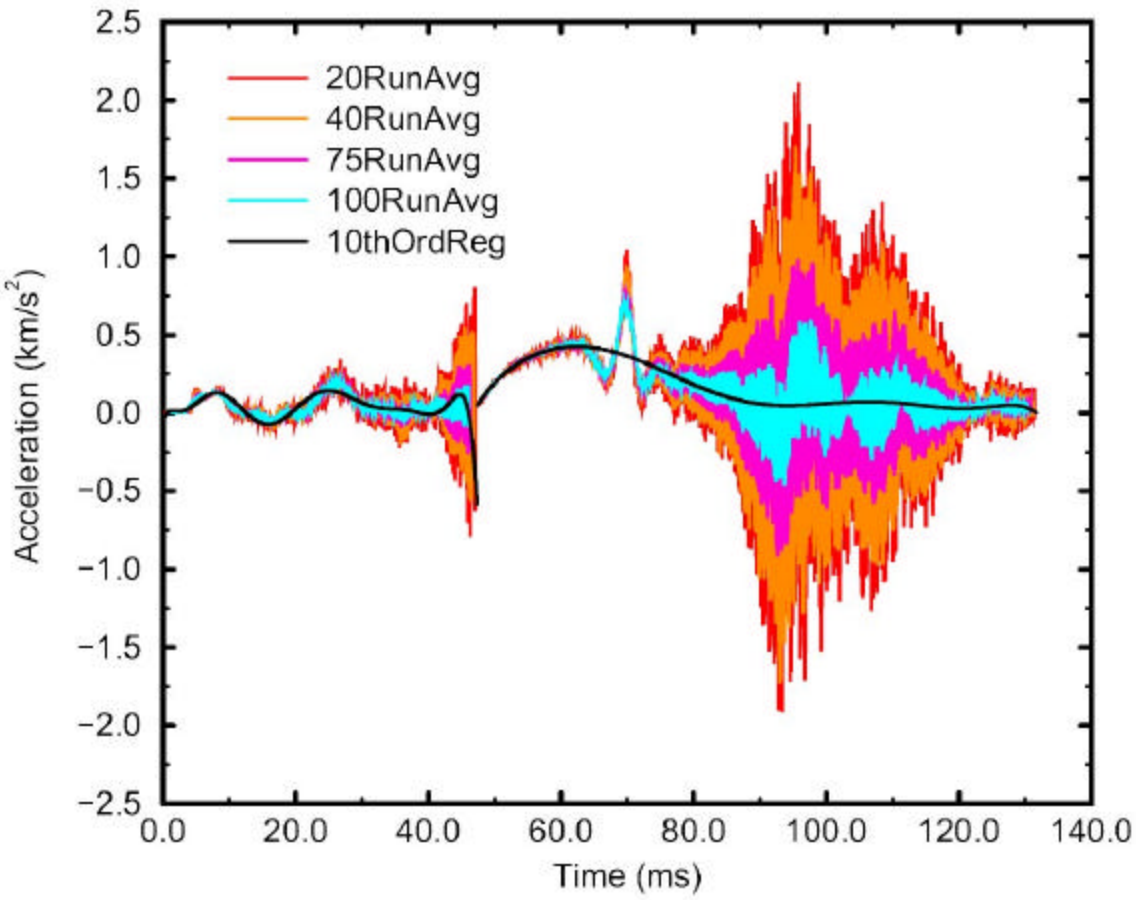
3DC ~ +1.0 km/s/s

2DC = +9.28 km/s/s

2DUb = 10.34 km/s/s

(2D Not Plotted)

Acceptor Stack X-Direction Acceleration: 3-D



Peak Values

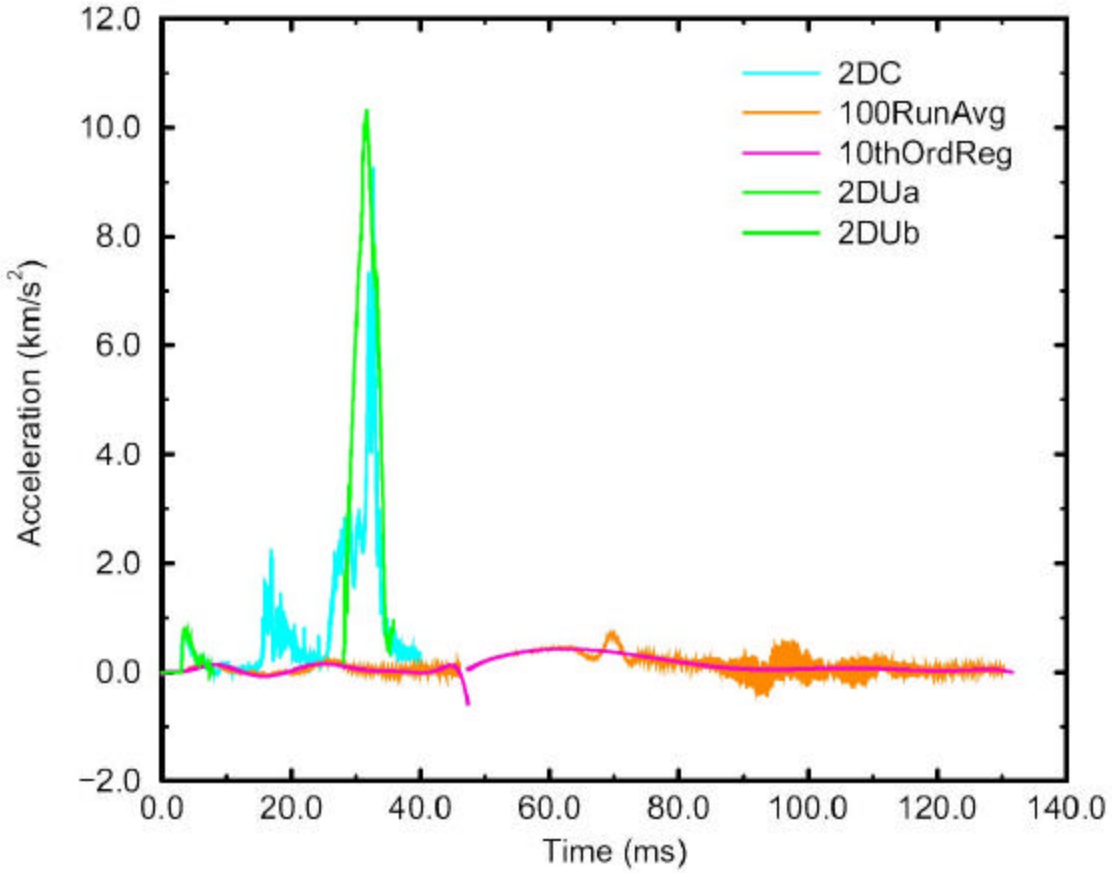
3DC ~ +1.0 km/s/s

2DC = +9.28 km/s/s

2DUb = 10.34 km/s/s

(2D Not Plotted)

Acceptor Stack X-Direction Acceleration: 3-D & 2-D



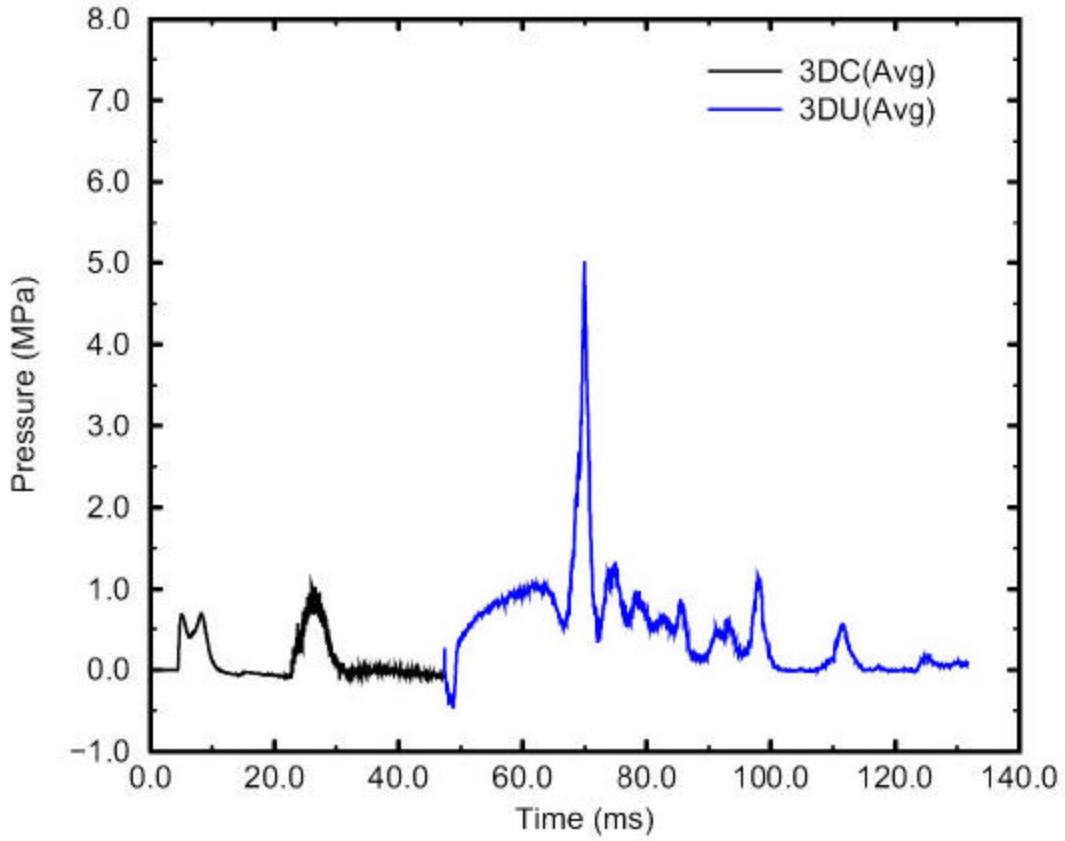
Peak Values

3DC ~ +1.0 km/s/s

2DC = +9.28 km/s/s

2DUb = +10.34 km/s/s

Acceptor Stack Left Surface Average Overpressure: 3-D



Peak Values

3DC = 1.05 MPa

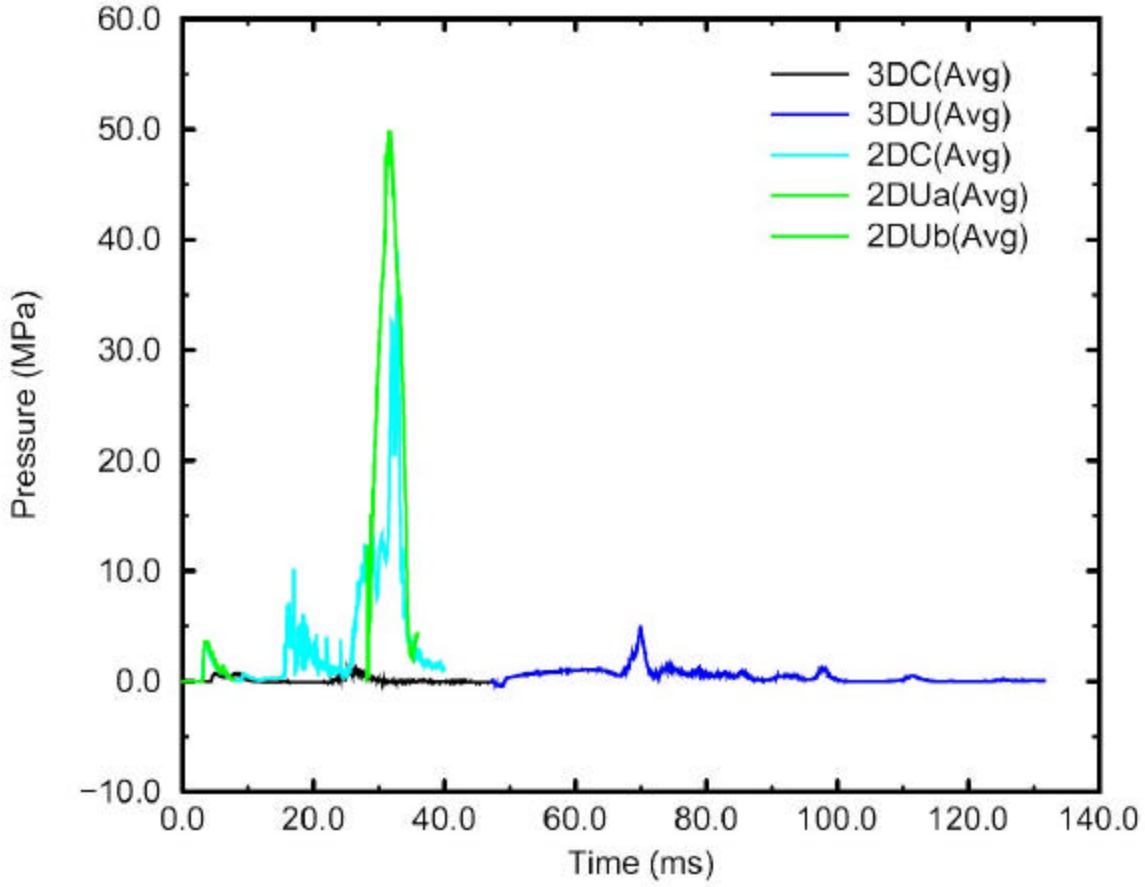
3DU = 5.02 MPa

2DC = 38.90 MPa

2DUb = 49.96 MPa

(2D Not Plotted)

Acceptor Stack Left Surface Average Overpressure: 3-D & 2-D



Peak Values

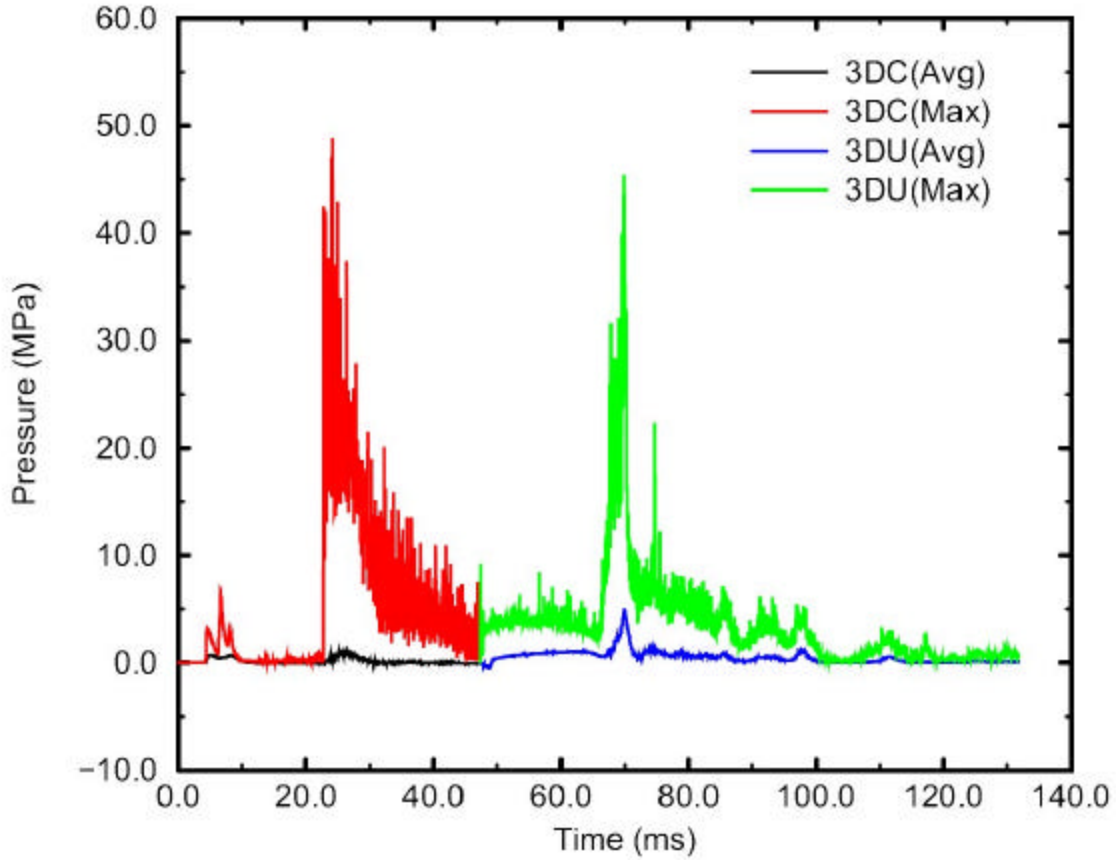
3DC = 1.05 MPa

3DU = 5.02 MPa

2DC = 38.90 MPa

2DUb = 49.96 MPa

Acceptor Stack Left Surface Average & Max. Overpressure: 3-D



Peak Values

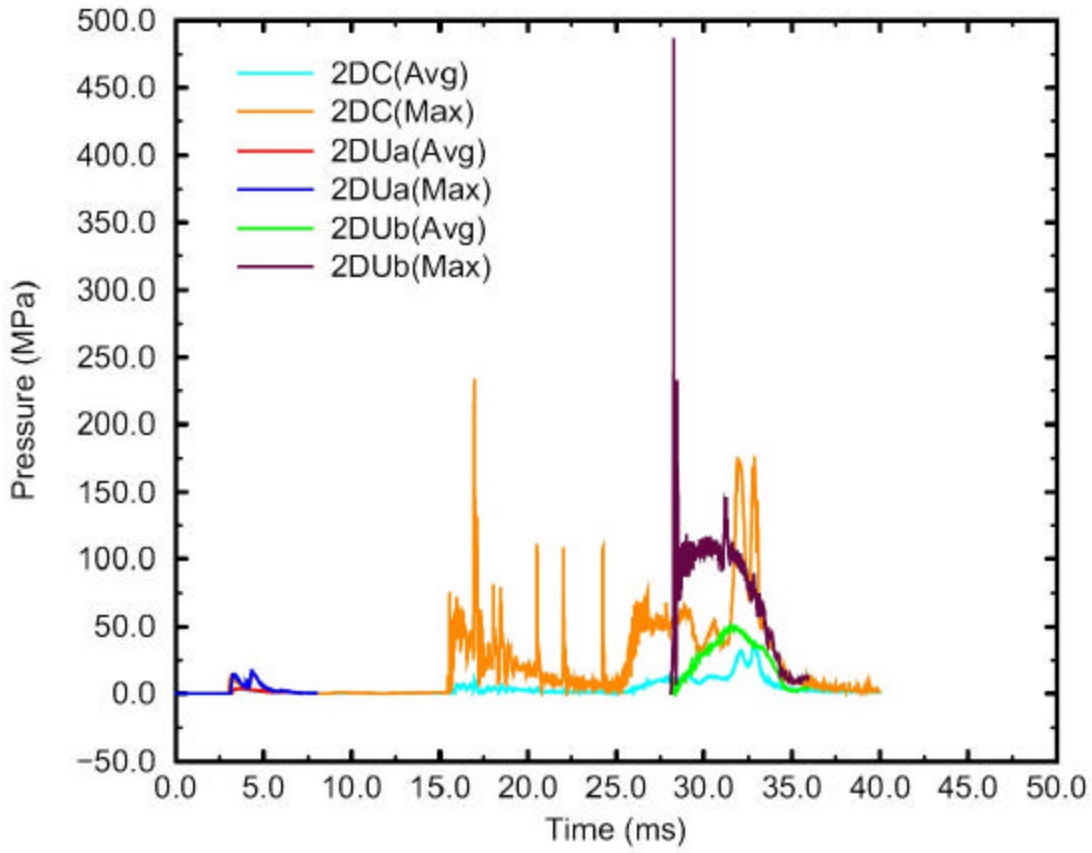
3DC = 1.05 MPa (Avg)

3DC = 48.80 MPa (Max)

3DU = 5.02 MPa (Avg)

3DU = 45.84 MPa (Max)

Acceptor Stack Left Surface Avg. & Max. Overpressure: 2-D



Peak Values

2DC = 38.90 MPa (Avg)

2DC = 233.7 MPa (Max)

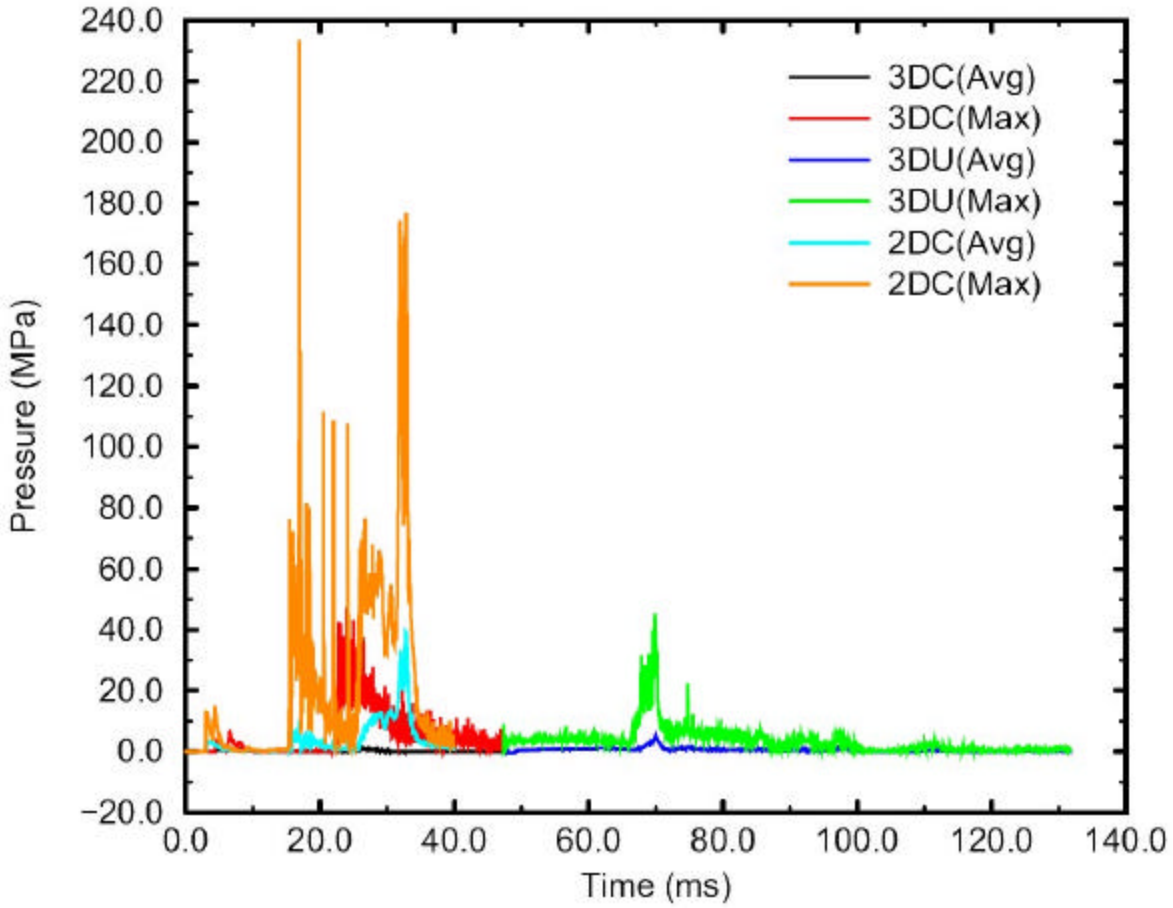
2DUa = 3.60 MPa (Avg)

2DUa = 17.78 MPa (Max)

2DUb = 49.96 MPa (Avg)

2DUb = 486.8 MPa (Max)

Acceptor Stack Left Surface Avg. & Max. Overpressure: 2-D



Peak Values

3DC = 1.05 MPa (Avg)

3DC = 48.80 MPa (Max)

3DU = 5.02 MPa (Avg)

3DU = 45.84 MPa (Max)

2DC = 38.90 MPa (Avg)

2DC = 233.7 MPa (Max)

Summary (1 of 2)

- Acceptor stack dynamics
  - Bulk velocity
    - Any 2-D Any 3-D
    - 39.95 m/s 16.07 m/s
  - Bulk acceleration
    - Any 2-D Any 3-D
    - 10.34 km/s/s 1.0 km/s/s
  - Left Surface Average Overpressure
    - Any 2-D Any 3-D
    - 49.96 MPa 5.02 MPa
  - Left Surface Maximum Overpressure
    - Any 2-D Any 3-D
    - 486.8 MPa 233.7 MPa

Summary (2 of 2)

- 3-D computations indicate that initiation from direct shock overpressure is very unlikely
  - Peak is 0.234 kbar
  - Liddiard & Forbes indicate 3 – 4 kbar is needed
- Computations do not address:
  - Crushing
  - Shearing
  - Munition-on-munition impact loading
  - Fragments
  - Cook-off of stack over time, with degradation of barricade
- Test at China Lake had one of two acceptors initiate at late time & after some translation
- Applicability to Q-D relief is a judgment call
- MSRC resources made computations possible